LAPPETED *ANOPLOCEPHALA* IN HORSES

BY

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AND

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(*Received for publication 22 July*, 1921)

PLATE XVII.

I. *ANOPLOCEPHALA RHODESIENSIS*, nom. nov.

About two hundred and fifty specimens of this parasite were collected by one of us in 1912, from eight zebra (*Equus burchelli*) in North Eastern Rhodesia.

TECHNIQUE. Most anatomical details were easily elucidated by the following procedure:—

The worms were stained, *en masse*, for several days in dilute acetic-acid-alum carmine, then washed and taken through the alcohols into clove oil. As soon as the worm was clear, it was placed under a binocular microscope and segments were detached, one at a time, by means of a surgical needle or cataract knife, beginning with the posterior segment. The segments were then mounted serially with the anterior surface upwards. This procedure was quite simple until about segments 10 to 15 were reached, when it was found that the segments were so small and close together that the detachment of single ones was difficult and tedious, and also often unsatisfactory. Anterior to this point sections were therefore cut with a microtome, when required. Horizontal sections were necessary, however, to determine the structure of the uterus, *e.g.*, the presence, or absence, of anterior and posterior outpocketings, and certain other details.

EXTERNAL ANATOMY.

The largest specimen measured 114 mm. long, 22 mm. broad and 3·25 mm. thick, and the smallest 14 mm. long, 4·25 mm. broad and

1·75 mm. thick. Specimens less than 30 mm. long were immature. Most of the larger worms approximated the following dimensions:— Length 90 mm., breadth 20 mm., thickness 3 mm.; number of segments, about two hundred and fifty.

The following measurements show the size of our largest worm as compared with measurements made by Führmann and Collin of the same species:—

	Long	Broad	Thick
Führmann	50 mm.	18 mm.	3 mm.
Collin	70 mm.	26 mm.	5-6 mm. ?
Our specimen	114 mm.	22 mm.	3.25 mm.

The smallest specimen contained ninety segments, and the posterior extremity was much narrower than the middle of the worm, and was rounded; the last few segments were longer (0·25 mm.) than the posterior segments in full-sized worms. A considerable number of Oestrid larvae (*Gastrophilus* sp.) were found firmly attached to many of the worms.

Head. The head is always conspicuous; it is cuboid, with a truncate anterior extremity; the breadth is considerably greater than the length. In large worms measuring 90 mm. the head is about 2 mm. long and 3·25 mm. broad.

Suckers. The suckers, which are situated on the anterior surface of the head, are directed straight forward. They are about 0·7 mm. in diameter, and their cups are surrounded by a definite muscular rim having a diameter of about 200μ. The suckers were separated from one another by more or less well marked grooves.

Lappets. Immediately behind each sucker is a large lappet. The length and breadth of the lappets varies considerably, possibly owing to contraction during fixation, but when they are fully extended they measure about 1·25 mm. long, 1·75 mm. broad, and the distance between the bases of the two dorsal or two ventral lappets is about 0·6 mm. In some specimens the lappets were globular and filled with liquid.

Segments. The segments are very shallow and are imbricated. Posteriorly, the worm increases gradually in size, the greatest breadth being usually about 1 cm. from the posterior extremity; it must be remarked, however, that the general shape of the worm varies considerably in different individuals, possibly owing to different degrees of contraction during fixation (Plate XVII).

INTERNAL ANATOMY.

Muscular system. Both the longitudinal and transverse muscles are strongly developed, and in transverse sections of mature segments the thickness of the former is about 130μ, and that of the latter about 60μ (fig. 3). The dorso-ventral muscle bands are not so well developed. A short but powerful muscle connects the internal extremity of the cirrus pouch with the transverse muscles of the ventral surface.

Nervous system. There are three longitudinal nerves on each side, the median being far the most prominent. The other two, dorsal and ventral, are slightly lateral to the median nerve and close to the transverse muscular layer (figs. 1 and 3).

Excretory system. The water vascular system is enormously developed. On each side there are two vessels, a very large ventral vessel having a diameter of about 35μ, and a much smaller dorsal vessel which appears to be interrupted from time to time. The ventral vessel is internal to the dorsal vessel which lies over the median nerve trunk. The remarkable development of the water vascular system is one of the most striking features in sections of the worm (figs. 2 and 3).

Genitalia. At least the whole of the posterior half of the worm is sterile, exhibiting no trace of genitalia, and, as in none of the specimens examined was there any evidence that segments had been shed, it is probable that the worm is passed entire in the faeces.

Testes. These first appear about segment 4 or 5, and they disappear about segment 25. They attain their maximum development between segments 11 and 15, where each testis measures from about 55μ to 90μ by 30μ to 70μ. They occupy the entire medullary parenchyma between the ventral excretory vessel on one side, and the cirrus pouch on the other; they never cross the ventral excretory vessel. They usually lie three or four deep in the dorso-ventral direction, but the larger ones may be only one or two deep (fig. 1).

Vas deferens. After running laterally from the testes for a short distance, the vas deferens dilates into the outer seminal vesicle, which usually lies ventral to the cirrus pouch, although it was observed occasionally to lie dorsal or median to the latter structure. It then narrows and enters the cirrus pouch, where it again dilates to form the inner seminal vesicle. The cirrus pouch is remarkably

long, and passes dorsal to the ventral water vessel and median nerve to reach the edge of the segment (figs. 1 and 2). The cirrus is long, slightly coiled, and is armed with very minute spines. Packets of spermatozoa of various shapes and sizes, but usually oval with pointed extremities, are abundant in both the outer and inner seminal vesicles. In the majority of mature segments, the measurements of these various structures are approximately as follows:—

Length of outer vesicula seminalis	550μ
Greatest breadth of vesicula seminalis	150μ
Length of inner vesicula seminalis	700μ
Greatest breadth of vesicula seminalis	200μ
Total length of cirrus pouch	1,000μ
Greatest breadth of cirrus pouch	100μ

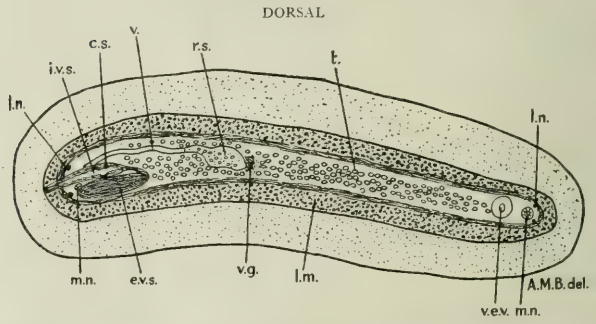

Fig. 1. *A. rhodesiensis.* Segment, viewed anteriorly, showing male genitalia. *c.s.*, cirrus sac; *e.v.s.*, external vesicula seminalis; *i.v.s.*, internal vesicular seminalis; *l.m.*, longitudinal muscles; *l.n.*, lateral nerves; *m.n.*, median nerve; *r.s.*, receptaculum seminis; *t.*, testes; *v.*, vagina; *v.e.v.*, ventral excretory vessel; *v.g.*, vitelline glands. × 40.

Ovary. This first appears about segment 24 and disappears about segment 34; it attains its maximum development about segment 30. The poral wing has a lateral diameter of about 1 mm. and the aporal wing of 2·2 mm. The median axis of the ovary is slightly on the pore side. The ovary consists of a series of vertical, club-shaped columns arising from a ventral horizontal base. The largest column measures about 170μ dorso-ventrally and 60μ laterally. The columns decrease in size towards the periphery of the ovary (fig. 2). In the antero-posterior direction they are never more than two deep.

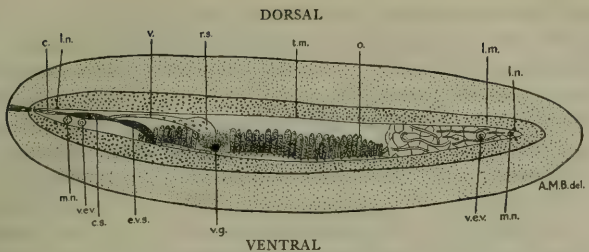

FIG. 2. *A. rhodesiensis.* Segment, viewed anteriorly, showing female genitalia. *c.*, cirrus; *c.s.*, cirrus sac; *e.v.s.*, external vesicula seminalis; *l.m.*, longitudinal muscles; *l.n.*, lateral nerves; *m.n.*, median nerve; *o.*, ovary; *r.s.*, receptaculum seminis; *t.m.*, transverse muscles; *v.*, vagina; *v.e.v.*, ventral excretory vessel; *v.g.*, vitelline glands. × 15.

Receptaculum and vagina. In segment 16 the vagina is well defined. From the pore it runs as a narrow tube ventral to the cirrus pouch for a short distance, then crosses it posteriorly to reach the dorsal surface. At this point it dilates and runs inwards just below the dorsal transverse muscle fibres, to enter the large receptaculum seminis. The receptaculum seminis is roughly club-shaped, with a greatly dilated internal extremity which is bent upon

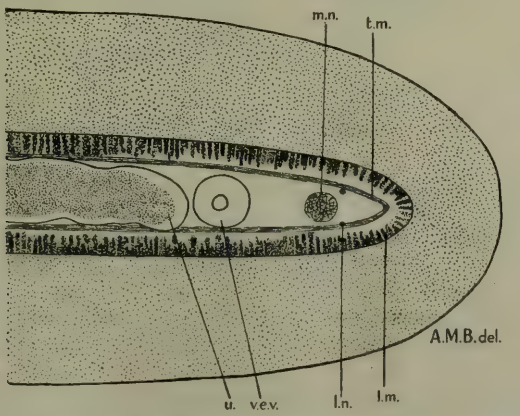

FIG. 3. *A. rhodesiensis.* Aporal extremity of segment, viewed anteriorly, showing uterus, longitudinal muscles, nerves and excretory vessels. *l.m.*, longitudinal muscles; *l.n.*, lateral nerves; *m.n.*, median nerve; *t.m.*, transverse muscles; *u.*, uterus; *v.e.v.*, ventral excretory vessel. × 40.

itself and almost reaches the ventral transverse muscle fibres. The vagina and receptaculum are always loaded with packets of spermatozoa (figs. 1 and 2). From its median surface there arises a small tube—the fertilisation canal—which runs dorsally, receiving the ducts of the shell gland, vitelline glands and ovary, and finally opens into the uterus (fig. 4). The genital pores are all dextral.

Vitelline glands. Appear for the first time about segment 7 and are mature about segment 40. They lie ventrally, close to the internal extremity of the receptaculum seminis (fig. 2), and consist of two wings which do not appear to be lobular as in some species of *Anoplocephala.*

Shell gland. As far as could be ascertained, it lies dorsal to the vitelline glands and is almost always obscured by them.

Uterus. Visible for the first time about segment 15 as a cell-string running across the segment. In segments 40 to 70 or 80 it is well developed and contains ova; at this point it is a straight wide tube devoid of outgrowths, it does not occupy the whole of the dorso-ventral diameter of the segment, nor does it extend laterally beyond the ventral excretory vessel (fig. 3). Further development beyond this stage was not seen, all the posterior segments being sterile.

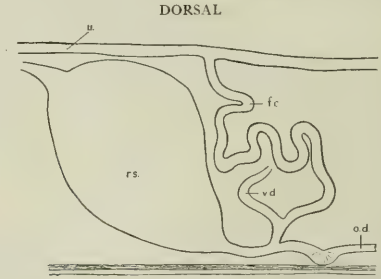

FIG. 4. *A. rhodesiensis.* Diagrammatic representation of fertilisation canal and connecting ducts. *f.c.*, fertilisation canal; *o.d.*, oviduct; *r.s.*, receptaculum seminis; *u.*, uterus; *v.d.*, vitelline duct. × 250.

Eggs. Notwithstanding the fact that about sixty worms were examined, no mature eggs were found. Eggs varying in size from 12μ to 25μ were often found in the same uterus. The largest eggs

seen had apparently three envelopes, the outer measuring about 25μ, the middle about 20μ, and the inner, which was completely filled with the embryo, about 11μ. These were, however, very rare, and by far the largest number of eggs seen measured about 12μ to 15μ in diameter. They contained large oil and yolk globules. All attempts to discover a pyriform body failed.

Scattered amongst the eggs in the uterus there occurred large numbers of other cellular structures apparently of a nutritive character (fig. 5). They varied in size, within wide limits, and many seemed to be in process of degeneration.

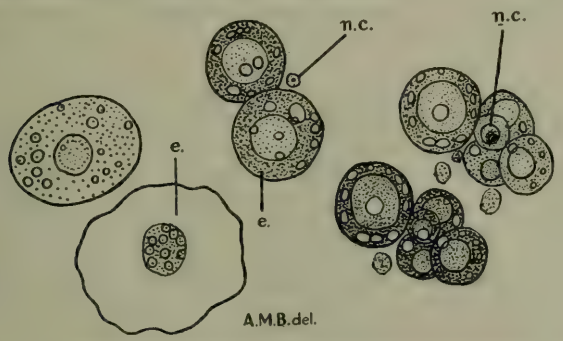

Fig. 5. *A. rhodesiensis.* Eggs and nutritive cells. *e.*, egg; *n.c.*, nutritive cells. × 730.

Diagnosis. The following are the chief diagnostic characters:—

1. Presence of lappets.
2. Its large size and numerous segments.
3. The enormous development of the water vascular system and longitudinal musculature.
4. The large number of sterile segments.

Abildgaard, in 1789, described a cestode from a horse, to which he gave the name *Taenia magna*; this worm had no lappets behind the head. Zeder, in 1800, also described an equine tapeworm, which had no lappets behind the head, to which he gave the name *T. plicata*. Rudolphi, in 1808, referring to *T. zebrae*, Sander, collected from a zebra, placed it amongst the species *dubiae*, and stated that it had affinities with *T. plicata*. Presumably, therefore,

T. zebrae of Sander did not possess lappets behind the head. Later, Cobbold expressed the opinion that *T. plicata* was a synonym of *T. magna*, Abildgaard.

The genus *Anoplocephala* was established by E. Blanchard in 1848.

Collin (1891) gave a general description of a worm collected from an African zebra which resembled *A. perfoliata* in possessing lappets behind the head. He named the species *Taenia zebrae*.

Gough (1908) states that *A. magna* (Zeder), var. *pediculata*, Railliet, were found by him in the horse, donkey and zebra, and that this species is not so rare in S. Africa as elsewhere. He points out that as Collin's worm possessed lappets, it must be distinct from *T. zebrae*, Sander, and is, therefore, a species without a name.

Führmann (1910) gave a careful description of Collin's species of *T. zebrae* from material obtained by the Kilimandjaro expedition, but did not deal with the synonymy, nor did he refer to Gough's paper. Führmann has been kind enough to send us a specimen of his *A. zebrae*, which we have examined, and which is undoubtedly the same species as the one described by us. It should be noted, however, that Führmann in his description fails to mention the interesting fact that the greater part of the worm is sterile (at least the posterior half), and furthermore, that he describes and figures ripe eggs furnished with a pyriform apparatus. These have never been seen by us, notwithstanding the fact that we have examined, minutely, the uterus from the ripest segments of over twenty of our specimens and also that of the specimen Führmann was good enough to send us.

Douthitt, in 1915, stated that *A. plicata* (Zeder) and *A. zebrae* are synonyms of *A. magna* (Abildgaard), and draws no distinction between Sander's *T. zebrae* and Collin's *T. zebrae*. He was apparently unaware of Führmann's paper, as he makes no reference to it.

It is clear that the worm which Collin named *T. zebrae* differs from Sander's *T. zebrae*, which is apparently identical with *T. magna*, Abildgaard, in that Collin's species is lappeted, whereas Sander's is not. *T. zebrae*, therefore, is a synonym of *T. magna*, and Collin's worm is, as Gough says, a species without a name. We propose to designate it *A. rhodesiensis*.

II. *ANOPLOCEPHALA PERFOLIATA* (Goeze, 1782), Blanchard, 1848.

The museum of this School contains the following collection of lappeted *Anoplocephala* from horses and mules:—

Horse A. Three specimens from Chesterfield, collected by A. W. Noel Pillers, December, 1909.

Horse B. Eight specimens from Chesterfield, collected by A. W. Noel Pillers, July, 1910.

Horse C. Four specimens from Sheffield, collected by A. W. Noel Pillers. No date.

Horse D. Two specimens from Manititlan, Mexico. No further information.

Mule E. Ten specimens from Argentine, collected in 1917.

As a result of preliminary examination of the anatomy of specimens from the above sources, we reached the conclusion that a number of different species were represented. On further examination, however, we were impressed with the fact that great variations occurred not only in worms from the same source, but even in different segments of the same specimen. This led us to the conclusion that the differences which at first we considered to be of specific value were of inconstant occurrence, and consequently that *A. perfoliata* (Goeze, 1782) is a species which exhibits considerable variation.

In this paper we propose to re-describe the worm, drawing attention to the variations which may occur.

External Anatomy.

The worms from the different sources were approximately the same size, varying from about 30 mm. to 45 mm. in length, except in the case of specimens from Horse B, which were fixed in a very extended condition and were of a gelatinous consistency. These were considerably longer, varying from 44 mm. to 70 mm. As a rule, the worms attain a maximum breadth of about 12 mm.

Head. This is prominent and almost cubical in shape; the length (2·5 mm.) is nearly equal to the breadth (3 mm.). In the specimens from Horse A the head was, however, distinctly broader (2·75 mm.) than long (1·5 mm.). The suckers and lappets resemble closely those of *A. rhodesiensis*.

Segments. The number of segments in an adult worm varies from about ninety to one hundred and thirty. The shape of the worm varies enormously, as will be seen in the photographs. Except that the worm is much less massive and consists of fewer segments than *A. rhodesiensis*, it exhibits no constant external difference from the latter species (Plate XVII).

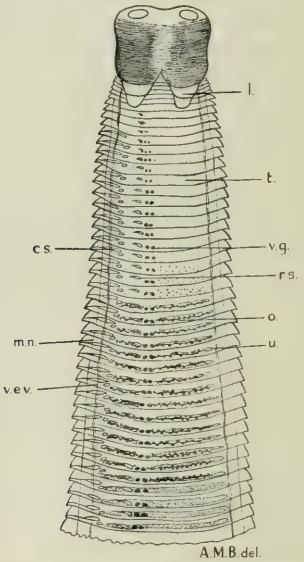

Fig. 6. *A. perfoliata.* Ventral view of anterior portion of a worm from Horse B; cleared in carbolic acid. *c.s.*, cirrus sac; *l.*, lappets; *m.n.*, median nerve; *o.*, ovary; *r.s.*, receptaculum seminis; *t.*, testes; *u.*, uterus; *v.e.v.*, ventral excretory vessel; *v.g.*, vitelline glands. × 6.

Internal Anatomy.

Muscular system. As in *A. rhodesiensis*, except that the longitudinal fibres are not so strongly developed.

Nervous system. The number of longitudinal nerves on each side varied. As a rule, there were three on each side, but in specimens from Horse B only the median nerve was constantly present, although the dorsal and ventral nerves were also seen in some segments. This variation was observed in the different

segments of the same worm, with the result that some segments exhibited only one nerve on each side, whilst in others three nerves were found on both sides, and in still others three nerves on one side and one on the other.

Excretory system. This differed from that of *A. rhodesiensis* only in that the vessels were not so large.

Genitalia. The segments become increasingly ripe towards the posterior extremity, and only a few sterile segments were found scattered here and there. This is in striking contrast to the long chain of sterile segments forming the posterior half of *A. rhodesiensis.*

Moreover, examination of the posterior extremities of worms from various horses left no reason to doubt that segments are shed.

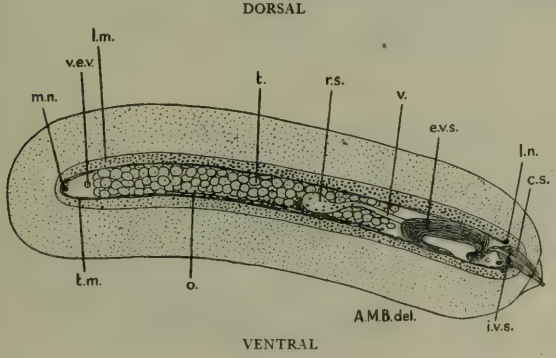

FIG. 7. *A. perfoliata.* Segment, viewed posteriorly, showing male genitalia. *c.s.*, cirrus sac; *e.v.s.*, external vesicula seminalis; *i.v.s.*, internal vesicula seminalis; *l.m.*, longitudinal muscles; *l.n.*, lateral nerves; *m.n.*, median nerve; *o.*, ovary; *r.s.*, receptaculum seminis; *t.*, testes; *t.m.*, transverse muscles; *v.*, vagina; *v.e.v.*, ventral excretory vessel. × 20.

Testes. These first appear about segment 12 and disappear about segment 30. They attain their maximum development between about segments 17 and 22. In all the specimens examined, excepting those from Horse B, the fully developed testes occupied the whole parenchyma between the aporal excretory vessel and the cirrus pouch (fig. 7). In Horse B, whilst this state of things was occasionally found, the testes, as a rule, were fewer in number and more limited in distribution, being congregated mainly in the dorsal

portion of the parenchyma; they did not extend laterally nearly so far as the aporal water vessel. There appears to be no doubt that in old worms the testes degenerate and entirely disappear. No trace of testes were found in the worms from Horse A.

Vas deferens. The appearance of the internal and external seminal vesicles varied considerably, and they did not exhibit any constant relationship one to the other. The outer seminal vesicle was usually ventral to the inner seminal vesicle, but this was not invariably the case; sometimes the former lay directly internal to the latter, or even dorsal to it.

Ovary. This first appears about segment 25 and disappears about segment 45. It attains its maximum development about segment 37. The poral wing has a diameter of about half that of the aporal wing. In structure it resembles that of *A. rhodesiensis*

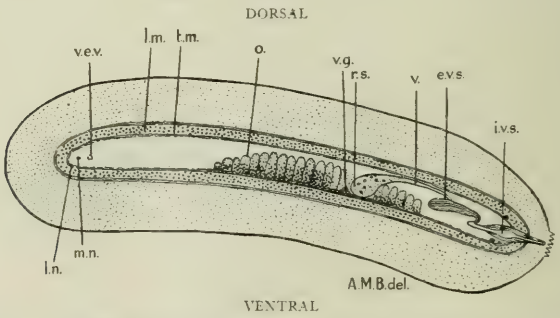

FIG. 8. *A. perfoliata.* Segment, viewed posteriorly, showing female genitalia. *e.v.s.*, external vesicula seminalis; *i.v.s.*, internal vesicula seminalis; *l.m.*, longitudinal muscles; *l.n.*, lateral nerves; *m.n.*, median nerve; *o.*, ovary; *r.s.*, receptaculum seminis; *t.m.*, transverse muscles; *v.*, vagina; *v.e.v.*, ventral excretory vessel; *v.g.*, vitelline glands. × 20.

(fig. 8). As in the case of the testes, the ovaries had entirely disappeared in worms from Horse A.

Receptaculum and vagina. The vagina appears early and is well defined in about segment 8. These structures resemble in all respects those of *A. rhodesiensis.*

Vitelline and shell glands. Similar to those of *A. rhodesiensis.*

Uterus. The uterus appears very early, about segment 12, as a delicate cell-string running across the segment. It gradually

enlarges and attains its full development only in the last few segments, where it is a wide tube completely filling the medullary parenchyma, but only occasionally crossing the ventral excretory vessels. In the fully developed uterus there are numerous anterior and posterior outpocketings, so that in anterior or posterior views of whole segments the uterus appears to be composed of a number of separate compartments (fig. 9). Sections, however, showed clearly

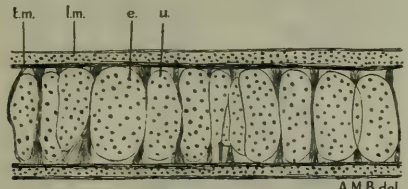

Fig. 9. *A. perfoliata.* Segment, viewed posteriorly, showing fully developed uterus. *e.*, egg; *l.m.*, longitudinal muscles; *t.m.*, transverse muscles; *u.*, uterus. × 40.

that the organ consisted of a central cavity with numerous anterior and posterior bulges between the dorso-ventral muscle fibres (fig. 10). To a certain extent there are bulges on the dorsal and ventral surfaces of the uterus, but they are not so prominent as those on the anterior and posterior surfaces. The degree of outpocketing varied in

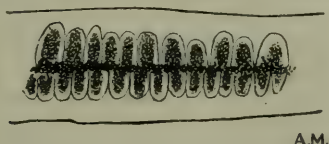

Fig. 10. *A. perfoliata.* Horizontal section of segment showing fully developed uterus. × 40.

different worms, sometimes being well marked and in other cases less obvious. Of the worms examined by us, the outpocketing was most marked in those from Mule E, and least marked in those from Horse B. Occasionally a well-developed uterus was seen which contained few or no eggs and a mass of debris.

Eggs. Fully mature eggs were found only in the last few segments. The diameter of the outer envelope was about 80μ, and that of the embryo about 16μ, whilst the length of the horns of the pyriform apparatus is about 18μ. Yolk granules about 7μ in

diameter occurred plentifully (fig. 11). As the egg matures, the middle envelope gradually shrinks, and its measurement is therefore of no value. In quite ripe eggs the horns of the pyriform apparatus

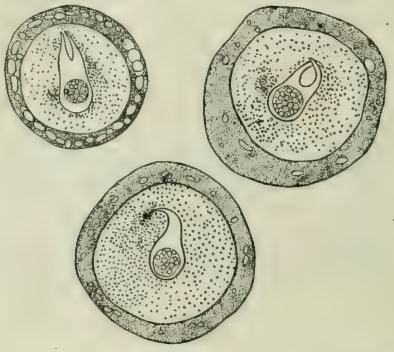

FIG. 11. *A. perfoliata.* Eggs showing pyriform apparatus. × 360.

are prolonged into very long, slender filaments which eventually unite with one another.

DIAGNOSIS. Führmann, as a result of a comparison between his own observations on the lappeted *Anoplocephala* from the zebra (called by him *A. zebrae*), and Kahane's description of *A. perfoliata*, gives the following points of difference between the two worms.

Cirrus pouch. In *A. zebrae* it extends beyond the longitudinal nerve and ventral water vessel, whilst in *A. perfoliata* it scarcely reaches the water vessel.

Vesicula seminalis. In *A. zebrae*, it is dorsal or ventral to the cirrus pouch, and in *A. perfoliata* it is posterior.

Ovary. Much more strikingly asymetrical in *A. zebrae* than in *A. perfoliata.*

We have carefully examined these points, and have reached the conclusion that they have no specific value. In the specimens of *A. perfoliata* examined by us, the cirrus pouch extended over the longitudinal water vessel and nerve to the edge of the segment, just as it does in the worm from the zebra. The relative position of the outer seminal vesicle and the cirrus pouch is inconstant, and finally

the aporal wing of the ovary is about twice the size of the poral wing in both worms.

In our experience, the only constant points of difference between the lappeted *Anoplocephala* of the zebra and horse, viz., *A. rhodesiensis* and *A. perfoliata*, are as follows:—

(1) *A. rhodesiensis* is much more massive than, and has almost twice as many segments as, *A. perfoliata*.

(2) The posterior half of *A. rhodesiensis* is entirely sterile, whereas in *A. perfoliata* the segments become increasingly ripe up to the posterior extremity of the worm.

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EXPLANATION OF PLATE XVII

Fig. 1. Photograph of *Anoplocephala rhodesiensis* showing bots attached. Natural size.

Fig. 2. Photograph of *Anoplocephala perfoliata* from Mule E, Horse B and Horse C, and of *Anoplocephala rhodesiensis* from a Zebra. (In order from left to right.) Natural size.

FIG. 1

FIG. 2